

CHEMICAL FORMULAE OF COMPOUNDS

A chemical formula is a symbolic representation of a compound, showing the elements present and their relative proportions.

Types of Chemical Formulae:

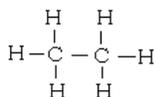
(a) Molecular Formula. This is one that shows the actual (exact) number of atoms of each element present in a compound.

Example: Glucose (C₆H₁₂O₆), Water (H₂O), Ethane (C₂H₆) and n-hexyne (C₆H₁₀)

(b) Empirical Formula. This is one that shows the simplest whole-number ratio of atoms of each element present in a compound. It is the simplest formula that expresses the simplest ratio of the atoms present in a given compound. This formula is obtained by experimental analysis of a compound and it can be related to a molecular formula only if the molecular weight is known.

Example: Glucose (CH₂O), Water (H₂O), Ethane (CH₃) and n-hexyne (C₃H₅)

(c) Structural Formula. This is one that shows how exact/actual number of atoms in a compound are arranged and bonded in a molecule. For example, the structural formula of ethane, C₂H₆ is



(d) Condensed Formula – A simplified version of the structural formula that shows the connectivity between exact number of atoms. Example: Ethanol - CH₃CH₂OH, ethane - CH₃CH₃

Significance of Chemical Formulae

- (i) Indicate the composition of a substance.
- (ii) Help in understanding chemical reactions.
- (iii) Essential in balancing chemical equations.

Important concepts about chemical formulae:

(a) In a chemical formula, the number written as a subscript after the symbol of an element indicates the number of atoms of that element which are chemically combined.

Consider examples of the chemical formulae below.

In water, H₂O - the two (2) represents the number of hydrogen atoms chemically combined. Therefore, water consist of two (2) hydrogen atoms and one (1) oxygen atom chemically combined together.

In sulphuric acid (H₂SO₄) - there are 2 atoms of hydrogen, 1 atom of sulphur and 4 atoms of oxygen chemically combined together.

In ammonium carbonate, (NH₄)₂CO₃ is the chemical formula which consists of 2 atoms of nitrogen, 8 atoms of hydrogen, 1 atom of carbon and 3 atoms of oxygen chemically combined.

(b) For groups of atoms (radicals), a bracket is used showing that they are being considered under the same valency.

For Example,

In calcium nitrate, Ca(NO₃)₂, the 2 indicates that there are 2 nitrate radicals (NO₃⁻). Both nitrogen and oxygen in nitrate are being considered under the same valency.

In aluminium sulphate, Al₂(SO₄)₃, the 3 shows that there are 3 sulphate radicals (SO₄²⁻), both the sulphur and oxygen in the sulphate are being considered under the same valency. Therefore, Al₂(SO₄)₃ consists of 2 atoms of aluminium and 3 sulphate radicals.

(c) A number put in-front of the formula of a compound indicates the number of molecules of the compound.

For Example,

$2\text{H}_2\text{SO}_4$ this means two molecules of sulphuric acid.

8HNO_3 means eight molecules of nitric acid.

3CO_2 means three molecules of carbon dioxide.

H_2O means one molecule of water.

(d) To be able to write a chemical formula, one has to know the symbol and valency of the atoms or radicals.

Steps taken in writing chemical formulae using valency of elements and radicals:

1. Identify from the name of the compound, the elements and radicals present e.g. in sodium chloride, there is sodium and chloride radical.

2. Write the symbol of the element or the formula of the radical separately, beginning with the one of a metal or ammonium radical followed by a nonmetal or radical.

3. Write the valency as superscripts to the right of the symbols written separately.

Valency is the combining power of an element or radical.

Examples of elements with their valency

Name and symbol of element	Valency	Name and symbol of element	Valency
Hydrogen, H	1	Scandium, Sc	3
Lithium, Li	1	Titanium, Ti	4, 3, 2
Beryllium, Be	2	Vanadium, V	5, 4, 3, 2
Boron, B	3	Chromium, Cr	6, 3, 2
Carbon, C	4	Manganese, Mn	7, 6, 4, 3, 2
Nitrogen, N	3	Iron, Fe	3, 2
Oxygen, O	2	Cobalt, Co	4, 3, 2
Fluorine, F	1	Nickel, Ni	4, 2
Sodium, Na	1	Copper, Cu	2, 1
Magnesium, Mg	2	Zinc, Zn	2
Aluminium, Al	3	Barium, Ba	2
Silicon, Si	4	Strontium, Sr	2
Phosphorus, P	3	Lead, Pb	2, 4
Sulphur, S	2	Tin, Sn	2, 4
Chlorine, Cl	1	Germanium, Ge	2, 4
Sodium, Na	1	Bromine, Br	1
Potassium, K	2	Iodine, I	1
Mercury, Hg	2, 1	Silver, Ag	1

Examples of some radicals and their valency

Name and formula of radical	Ion	Valency	Name and formula of radical	Ion	Valency
Ammonium (NH ₄)	NH ₄	1	Dichromate (Cr ₂ O ₇)	Cr ₂ O ₇ ²⁻	2
Hydroxide (OH)	OH ⁻	1	Oxalate or Ethanedioate (C ₂ O ₄)	C ₂ O ₄ ²⁻	2
Peroxide (O ₂)	O ₂ ²⁻	2	Ethanoate or Acetate (CH ₃ COO)	CH ₃ COO ⁻	1
Carbonate (CO ₃)	CO ₃ ²⁻	2	Phosphite (PO ₃)	PO ₃ ³⁻	3
Hydrogen carbonate (HCO ₃)	HCO ₃ ⁻	1	Dihydrogen phosphite (H ₂ PO ₃)	H ₂ PO ₃ ⁻	1
Nitrate (NO ₃)	NO ₃ ⁻	1	Hydrogen phosphite (HPO ₃)	HPO ₃ ²⁻	2
Nitrite (NO ₂)	NO ₂ ⁻	1	Chlorate (ClO ₃)	ClO ₃ ⁻	1
Sulphate (SO ₄)	SO ₄ ²⁻	2	Chlorite (ClO)	ClO ⁻	1
Hydrogen sulphate (HSO ₄)	HSO ₄ ⁻	1	Iodate (IO ₃)	IO ₃ ⁻	1
Sulphite (SO ₃)	SO ₃ ²⁻	2	Permanganate or Manganate(VII) (MnO ₄)	MnO ₄ ⁻	1
Hydrogen sulphite (HSO ₃)	HSO ₃ ⁻	1	Methanoate (HCOO)	HCOO ⁻	1
Phosphate (PO ₄)	PO ₄ ³⁻	3	Etc		
Dihydrogen phosphate (H ₂ PO ₄)	H ₂ PO ₄ ⁻	1			
Hydrogen phosphate (HPO ₄)	HPO ₄ ²⁻	2			

4. Compare the valency and if the valency is;

- the same, cancel them out and write the symbols/formula close to each other.
- different, but have a common factor, reduce them to the simplest ratio then interchange the valency and write them as subscripts to the right of the symbol or formula of the radical.
- different and have no common factor, interchange them and write them as subscripts to the right of the symbol or formulae of radical.

Item:

At Greenhill Secondary School in Kampala, the Senior Two science class is conducting a community project on **chemicals commonly found in everyday life**. Their science teacher, Mr. Okello, asks the learners to investigate substances used at home, in agriculture, and in school laboratories.

During the investigation, the learners visit a nearby shop and observe several products such as table salt, sugar, baking soda, washing soda, fertilizers, and cleaning agents. Mr. Okello explains that these substances are made of **chemical compounds**, each with a specific chemical formula that helps scientists identify their composition.

The learners are required to record the compounds they find and present them to the class during a science exhibition. Each group must identify several compounds and write down their **correct chemical formulae**.

Task: As a chemistry student, identify **at least ten chemical compounds** that learners may find in everyday life, write the **correct chemical formula** for each compound while showing your working clearly and present your findings in a **clear table format**.

Writing Chemical formulae of hydrated compounds:

The steps for writing the chemical formula of a hydrated compound from its given name are:

- Identify the name of the anhydrous form in the compound.

e.g. Copper(II) sulphate from the name *Copper(II) sulfate pentahydrate*.

- Write the chemical formula of the anhydrous form (the compound without water) by combining the elements and / or radicals correctly using their valency. i.e. CuSO_4

- Identify the prefix that shows the number of water molecules (such as mono-, di-, tri-, penta-, etc.).

i.e. Prefix: *Penta* \rightarrow 5 water molecules

- Write the water of crystallization as H_2O (and place them after the salt formula as a coefficient).

- Place a dot (.) between the salt formula and the water molecules to show water of crystallization.

- Write the number of water molecules before according to the prefix. i.e. the number of water molecules present in the compound (usually given or obtained from calculations) and combine them to obtain the hydrated compound formula in the form: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

Writing Chemical formulae of compounds from common names containing prefixes di, tri, etc:

When writing the chemical formula from a common name that contains prefixes such as di-, tri-, tetra-, penta-, etc., you follow these logical steps:

- Identify the elements in the name. Separate the name into the elements mentioned.

Example: triiron tetraoxide \rightarrow iron and oxygen.

- Write the symbols of the elements. Write the correct chemical symbols for the elements in the same order they appear in the name. i.e. Iron \rightarrow Fe Oxygen \rightarrow O

- Interpret the numerical prefixes. The prefixes show how many atoms of each element are present.

i.e. triiron \rightarrow 3 Fe atoms tetraoxide \rightarrow 4 O atoms

- Write the numbers as subscripts. Place the numbers indicated by the prefixes as subscripts after each element symbol. i.e. $\text{Fe}_3 \text{O}_4$

- Combine the symbols to form the formula. Write the complete formula.

i.e. triiron tetraoxide \rightarrow Fe_3O_4

✓ Summary of the procedure:

- Identify the elements in the compound name.

- Write their chemical symbols.

- Determine the number of atoms from the prefixes.

- Write these numbers as subscripts.

- Combine the symbols to obtain the chemical formula.

CHEMICAL EQUATIONS

A chemical equation represents a chemical reaction using symbols and formulas.

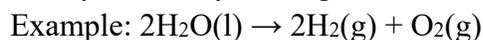
There are many chemical reactions some of which include;

(a) Direct Combination Reaction. This is a reaction in which two or more chemical substances combine to form a single product.

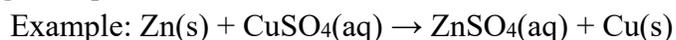
Example: $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$

(b) Decomposition Reaction. This is a reaction in which a compound breaks down into smaller simpler substances.

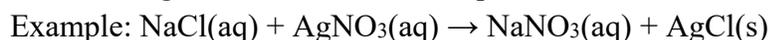
This is mainly caused by heating, electric current in electrolysis and other conditions.



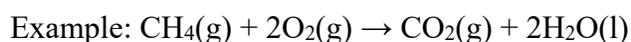
(c) Single Displacement Reaction. This is a reaction in which one element replaces another in a compound.



(d) Double Displacement Reaction / double decomposition or precipitation. This is a reaction in which two compounds exchange ions to form new compounds.



(e) Combustion Reaction. This is a reaction in which a substance reacts with oxygen, producing energy.



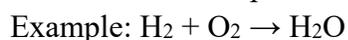
(f) Neutralisation reaction. This is a reaction in which an acid and a base to form a salt and water only.



Types of Chemical Equations:

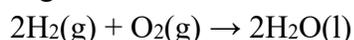
(a) Word Equation: This is an equation that uses names of chemical substances to describe the reactants and products. Example: Hydrogen + Oxygen \rightarrow Water

(b) Skeleton Equation: This is an equation that uses chemical formulae and symbols of chemical substances to describe the reactants and products but it is not balanced.



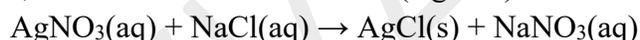
(c) Symbolic Equation: This is an equation that uses chemical formulae and symbols of chemical substances to describe the reactants and products and shows the correct proportions of reactants and products, obeying the Law of Conservation of Mass. i.e. It is balanced.

The Law of Conservation of mass states that 'mass cannot be created or destroyed' in a chemical reaction but it only changes form'. This means that the total mass of reactants must equal the total mass of products. Example:



(d) Ionic Equation: This is an equation that represents the chemical reaction by showing the ions involved, caused by the dissociation of soluble compounds in aqueous solutions. There are two main types:

(i) Full/Complete Ionic Equation: This breaks down all soluble ionic compounds into their respective ions. For example, the reaction of silver nitrate (AgNO_3) with sodium chloride (NaCl).



In ionic form: $\text{Ag}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{Na}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$

(ii) Net Ionic Equation: This is the commonly used ionic equation that removes spectator ions (ions that do not change or take part in the reaction). It is only the reacting ions that are shown.



Components of a chemical equation:

(a) **Formulae of reactants and products.** These represent compounds reacting and compounds being formed during a chemical reaction respectively.

(b) **State symbols.** A state symbol is one small letter or two small letters that represent the physical state of a compound. They are written after the formulae and enclosed in brackets. There are four state symbols used. These are aqueous solution (aq); liquid (l); solid state(s) and gaseous state (g).

(c) **The plus (+) sign.** The plus sign on the left-hand side of the equation means 'reacts with' and the one at the right-hand side of the equation means 'and'.

(d) **The arrow.** This means to produce and the arrow head points to the products.

Importance of Chemical Equations

(a) It predicts the amounts of reactants needed and that of the products formed.

(b) Helps in industrial and laboratory chemical processes.

(c) Essential in environmental and medical studies.

Examples of Real-life applications of equations

1. Cooking and Baking (Decomposition Reactions)

Scenario: When baking a cake, baking powder (sodium bicarbonate / sodium hydrogen carbonate) decomposes to release carbon dioxide gas, making the cake to expand.

Chemical Equation: $2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$

Application: Carbon dioxide bubbles expand in the batter (a semi-liquid mixture of flour, eggs and milk or water), creating a fluffy (light and airy) texture.

2. Respiration (Cellular Energy Production)

Scenario: Animals breathe in oxygen to break down glucose and release energy.

Chemical Equation: $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) + \text{energy (ATP)}$

Application: This reaction provides the energy needed for movement, brain function, and survival.

3. Car Airbags Deployment (Decomposition of Sodium Azide)

Scenario: In a car crash, airbags inflate instantly due to a rapid chemical reaction.

Chemical Equation: $2\text{NaN}_3(\text{s}) \rightarrow 2\text{Na}(\text{s}) + 3\text{N}_2(\text{g})$

Application: The decomposition of sodium azide releases nitrogen gas, inflating the airbag in milliseconds.

4. Cleaning with Bleach (Oxidation Reactions)

Scenario: Household bleach is used to remove stains and also kill bacteria.

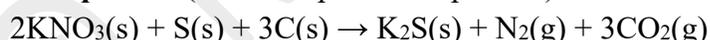
Chemical Equation: $\text{NaClO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HOCl}(\text{aq}) + \text{NaOH}(\text{aq})$

Application: Hypochlorous acid (HOCl) acts as a powerful disinfectant, breaking down stains and germs.

5. Fireworks and Explosions (Combustion Reactions)

Scenario: Fireworks explode in the sky, producing bright colors and loud sounds.

Chemical Equation (for black powder explosion):



Application: This reaction produces heat, gases, and sparks that create the visual and sound effects.

6. Digestion of Food (Acid-Base Reactions)

Scenario: The stomach contains hydrochloric acid (HCl), which helps digest food by breaking down proteins.

Chemical Equation (for protein digestion): $\text{Protein} + \text{HCl} \rightarrow \text{Smaller Peptides}$

Application: The reaction helps in the absorption of nutrients from food.

7. 🔥 Rusting of Iron (Corrosion)

Scenario: Iron objects exposed to air and water develop rust over time.

Chemical Equation: $4\text{Fe}(\text{s}) + 3\text{O}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{Fe}(\text{OH})_3(\text{s})$

Then over time; $\text{Fe}(\text{OH})_3(\text{s}) \rightarrow \text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}(\text{s})$ - *hydrated iron(III) oxide (rust)*

Application: Understanding this reaction helps in preventing rust using protective coatings in a number of ways.

Explanation: Iron reacts with oxygen and water to form rust, a reddish-brown flaky substance.

8. Blood Clotting (Fibrin Formation)

Scenario: When you get a cut, your blood clots to stop excessive bleeding.

Chemical Equation (Simplified Reaction): Fibrinogen + Thrombin \rightarrow Fibrin (clot)

Application: This reaction is crucial for wound healing and preventing blood loss.

9. 🚗 Automobile Pollution.

Question: Cars release nitrogen dioxide (NO_2), a harmful gas. When NO_2 mixes with rainwater, it forms an acid. Identify the acid formed and write its chemical equation.

Answer: Nitric acid (HNO_3) is formed.

Chemical Equation: $4\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 4\text{HNO}_3(\text{aq})$

Explanation: This process leads to acid rain containing **nitric acid (HNO_3)**, which has several environmental and structural shortcomings, including:

10. 🔥 Combustion in Daily Life.

Question: A gas stove burns methane (CH_4) for cooking. What is the balanced chemical equation for the combustion of methane in the presence of oxygen?

Answer: $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$

Explanation: This is a combustion reaction where methane reacts with oxygen to form carbon dioxide and water, releasing energy.

11. 🍷 Cleaning with Vinegar and Baking Soda.

Question: Mixing vinegar (acetic acid - CH_3COOH) and baking soda (NaHCO_3) causes fizzing. What gas is released and what's the chemical equation?

Answer: Carbon dioxide (CO_2) is released.

Chemical Equation: $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaHCO}_3(\text{s}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

Explanation: This reaction is used in homemade cleaning solutions and science experiments (like volcano models).

12. 🦷 Tooth Decay.

Question: When bacteria break down sugar in your mouth, they produce acids that react with the calcium compound in enamel ($\text{Ca}_5(\text{PO}_4)_3\text{OH}$). Which acid is typically involved and what is the effect?

Answer: Lactic acid ($\text{C}_3\text{H}_6\text{O}_3$) is produced, which reacts with the enamel causing tooth decay.

Simplified Reaction: $\text{Ca}_5(\text{PO}_4)_3\text{OH}(\text{s}) + \text{Acid} \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{PO}_4^{3-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

(simplified representation)

Explanation: Acid dissolves the calcium phosphate in the enamel, leading to cavities.

Steps to Balance a Chemical Equation

Balancing chemical equations ensures that the number of atoms of each element is the same on both sides of the equation, maintaining the law of conservation of mass.

The general rules for balancing equations include:

(a) Write the correct formulae or symbols of the reactants on the left-hand side and the correct formulae of products on the right-hand side of the equation. The reactants and products are separated by an arrow pointing towards the products.

(b) Write the state symbol (physical state) of the reactants and products in small letters after each formula or symbol and enclose them in brackets.

(c) Count the number of atoms of each element present on both sides of the equation.

(d) Adjust the coefficients (whole numbers) written before the formula or symbol of reactants and products but not the subscripts (numbers within the formulae), in order to balance the atoms.

Balance metals first, then nonmetals. Hydrogen atoms, oxygen atoms and diatomic molecules (Cl_2 , H_2 , O_2) are preferably balanced last.

(e) Check to ensure the equation obeys the Law of Conservation of Mass.

Practice questions for balancing equations in Real-Life Application

1. Cooking and baking.

Scenario: Jane is in the kitchen baking a cake. She realizes that just like how ingredients must be in the right proportions to bake a perfect cake, chemicals in a reaction must also be balanced. She observes that when vinegar (acetic acid) reacts with baking soda (sodium bicarbonate), it produces carbon dioxide gas, water, and sodium acetate.

Question: Write the chemical equation for the reaction between acetic acid (ethanoic acid) and sodium bicarbonate (sodium hydrogen carbonate) and explain why it is necessary to balance chemical equations in real-life situations.

2. Environmental Science Connection.

Scenario: A factory releases sulphur dioxide gas into the atmosphere, which reacts with oxygen and water to form sulphuric acid, a major component of acid rain.

Question: Write and balance the chemical equation for the formation of sulphuric acid from sulphur dioxide, oxygen, and water. How does balancing this equation help scientists understand and control pollution?

3. Industrial Chemistry.

Scenario: A fertilizer company manufactures ammonia using nitrogen gas from the air and hydrogen gas from natural gas. The reaction follows the Haber process, which must be carefully controlled for efficiency.

Question: Write the equation for the formation of ammonia from nitrogen and hydrogen and explain why industries must ensure that reactions are balanced when producing chemicals.

4. Health and Medicine.

Scenario: A doctor explains to a patient that hydrogen peroxide is used as a disinfectant because it breaks down into water and oxygen, killing bacteria in the process.

Question: Write the unbalanced equation for the decomposition of hydrogen peroxide. Balance the equation and explain why the correct proportions of reactants and products are important in medical applications.

Research-based Items:

1. Sodium Reacting with Excess Oxygen (Formation of Sodium Peroxide).

During a science exhibition at a secondary school in **Kampala**, a teacher demonstrates how reactive alkali metals are stored in paraffin oil. When a small piece of sodium is accidentally exposed to excess air, it burns with a bright yellow flame and forms a pale solid.

Task: Explain why sodium must be stored under oil. Describe the product formed when sodium reacts with excess oxygen using an equation and state two dangers of leaving sodium exposed to air in a humid environment like Uganda's.

2. Ammonia Burning in Oxygen (Without Catalyst).

At a fertilizer blending plant in **Jinja**, ammonia gas leaks near a hot surface and reacts with oxygen in air.

Task: Describe what happens when ammonia burns in oxygen without a catalyst. Identify the gaseous products formed and explain why such a reaction could pose environmental concerns.

3. Ammonia Oxidation in Presence of Platinum (Ostwald Process Step).

At an industrial chemistry workshop in **Tororo**, learners study nitric acid production. The instructor explains that ammonia is heated in oxygen in the presence of platinum gauze.

Task: State the products formed in this reaction. Explain the role of platinum and name one industrial importance of the reaction in Uganda's agricultural sector.

4. Decomposition of Potassium Chlorate.

In a rural secondary school laboratory in **Mbarara**, a teacher heats potassium chlorate crystals to prepare oxygen gas for an experiment.

Task: Describe what happens when potassium chlorate is heated. Name the solid and gaseous products formed. Explain how the oxygen collected can be tested.

5. Reaction of Chlorine with Heated Iron.

At a water treatment plant near **Lake Victoria**, chlorine gas is used for disinfection. During maintenance, chlorine accidentally passes over hot iron pipes.

Task: Explain the reaction that occurs between chlorine gas and heated iron. Identify the product formed and describe its physical appearance.

6. Decomposition of Lead(II) nitrate.

In a chemistry practical lesson at a school in **Gulu**, students heat lead(II) nitrate crystals. They observe a crackling sound and brown fumes.

Task: Describe the observations made during the experiment. Name the solid residue and gases produced. Explain why the experiment should be conducted in a well-ventilated area.

7. Copper with Cold Dilute Nitric Acid.

A scrap metal dealer in **Mbale** experiments with cleaning copper wires using dilute nitric acid.

Task: Describe what happens when copper reacts with cold dilute nitric acid. Identify the colour of the solution formed and the gas produced. State one laboratory test for the gas evolved.

8. Copper with Hot Concentrated Nitric Acid.

In an industrial laboratory in **Kampala**, a technician uses hot concentrated nitric acid to dissolve copper turnings.

Task: Compare the reaction of copper with concentrated nitric acid to that with dilute nitric acid. Identify the gas evolved and describe its colour and environmental impact.

9. Steam Reacting with Heated Iron.

At a vocational institute in **Arua**, students studying metal fabrication pass steam over red-hot iron.

Task: Describe the products formed when steam reacts with heated iron. State the colour of the solid formed and explain one industrial significance of the hydrogen gas produced.

10. The Haber Process.

At a fertilizer manufacturing company in **Jinja**, engineers combine nitrogen from air and hydrogen gas under high temperature and pressure in the presence of a catalyst.

Task: Name the process used and identify the product formed. Explain why this process is important for improving agricultural productivity in Uganda.

11. Reduction of Lead(II) Oxide by Ammonia.

During a practical lesson in **Fort Portal**, learners pass ammonia gas over heated lead(II) oxide.

Task: Explain the reaction that occurs. Identify the solid formed and name the other products. State whether ammonia acts as a reducing or oxidizing agent.

12. Reaction of Iron(III) Oxide with Sulphuric Acid.

At a metal processing workshop in **Mukono**, rust (iron(III) oxide) is treated with sulphuric acid.

Task: Describe the reaction between iron(III) oxide and sulphuric acid. Identify the products formed and explain how this reaction relates to removal of rust.

13. Reaction of Trilead Tetraoxide with Concentrated Sulphuric Acid

In a battery recycling plant in **Kampala**, red lead is treated with concentrated sulphuric acid during analysis.

Task: State the products formed when trilead tetraoxide reacts with hot concentrated sulphuric acid. Identify the white solid formed and mention one safety precaution during the process.

14. Tin with Hot Concentrated Sulphuric Acid

At a metal fabrication industry in **Jinja**, tin roofing off-cuts are tested with hot concentrated sulphuric acid.

Task: Describe the reaction that occurs. Name the salt formed and the gas produced. Suggest one method of testing the gas.

15. Potassium Dichromate with Concentrated Hydrochloric Acid

In a forensic laboratory in **Entebbe**, a chemist reacts potassium dichromate crystals with hot concentrated hydrochloric acid.

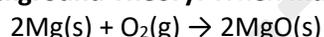
Task: Describe the colour change observed during the reaction. Identify all products formed and explain why the reaction must be carried out in a fume cupboard.

 **Experiment: Determining the Empirical Formula of Magnesium Oxide**

 **Objective:**

To determine the empirical formula of magnesium oxide by reacting magnesium with oxygen and analyzing the mass changes.

 **Background Theory:** When magnesium reacts with oxygen, it forms magnesium oxide:



The empirical formula represents the simplest whole-number ratio of atoms in a compound. By measuring the mass of magnesium before reaction and the mass of magnesium oxide after reaction, we can calculate the mass of oxygen that reacted and determine the mole ratio.

 **Materials and Apparatus:** Magnesium ribbon (Mg), Crucible with lid, Crucible tongs, Bunsen burner, Analytical balance (± 0.01 g), Wire gauze and tripod, Sandpaper (to clean Mg ribbon)

 **Experimental Procedure:**

Preparation of Magnesium: Clean magnesium ribbon with sandpaper to remove surface oxide and coil it loosely.

Mass of Empty Crucible: Weigh clean, dry crucible with lid and record the mass.

Mass of Crucible + Magnesium: Place magnesium in crucible. Weigh again and record.

Heating: Place crucible on tripod. Heat gently at first, then strongly. Lift lid slightly occasionally to allow oxygen in. Continue heating until reaction is complete (white powder forms).

Cooling and Final Mass: Allow crucible to cool. Weigh crucible + magnesium oxide.

Reheat, cool, and reweigh to ensure constant mass.

 **Sample Experimental Data:**

Measurement	Mass (g)
Mass of empty crucible	25.60

Measurement	Mass (g)
Mass of crucible + Mg	26.08
Mass of crucible + MgO	26.40

Calculations:

Mass of Magnesium = $26.08 - 25.60 = 0.48\text{g}$

Mass of Magnesium Oxide = $26.40 - 25.60 = 0.80\text{g}$

Mass of Oxygen = $0.80 - 0.48 = 0.32\text{g}$

Conversion of the Mass to Moles

Molar mass of Mg = 24.3 g/mol . Hence Moles of Mg = $0.48 / 24.3 = 0.0198\text{ moles}$

Molar mass of O = 16.0 g/mol . Hence Moles of O = $0.32 / 16.0 = 0.0200\text{ moles}$

Mole Ratio = Mg : O $0.0198 : 0.0200$ Divide both by smallest value: 1:1

Empirical Formula:

MgO

Observations:

Magnesium burns with a bright white flame and a white powder (magnesium oxide) is formed.

Some white smoke may escape. The crucible becomes very hot and glows red.

Sources of Error:

- Loss of magnesium oxide smoke during heating.
- Incomplete reaction.
- Reaction with nitrogen forming magnesium nitride.
- Not heating to constant mass.
- Oxide layer not removed before weighing.

Safety Precautions:

- Do not look directly at burning magnesium.
- Use tongs for handling hot equipment.
- Wear safety goggles.
- Tie back long hair.

Conclusion:

From experimental data, the mole ratio of magnesium to oxygen was approximately 1:1. Therefore, the empirical formula of magnesium oxide is **MgO**, consistent with the known formula of magnesium oxide.